Measurement of a High Gaussian-content Corrugated Horn for a W-band Gyro-TWA

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***Abstract*—A corrugated horn was design to achieve high Gaussian content horn and low reflection over an operating frequency range of 90 – 100 GHz was designed and verified by measurement with a vector network analyzer (VNA). The corrugated horn will be used in a W-band gyro-TWA experiment to convert TE_{11} mode in circular waveguide into a Gaussian-like HE_{11} mode. The measurement shows a lower than -30 dB reflection over the desired frequency range, and the Gaussian percentage is about 99.4%, which is close to the simulation results.**

I. INTRODUCTION

Gyrotron traveling wave amplifiers (Gyro-TWAs) can find potential applications in plasmas diagnostics, remote sensing, electron spin resonance spectroscopy, and so on. A W-band gyro-TWA is currently been experimentally studied for cloud profiling radar in university of Strathclyde. The gyro-TWA is designed to operate in a wide frequency range of 90 -100 GHz, and to generate output radiation ~5 kW when driven by a 40 kV, 1.5 A beam. The gyrotron backward wave oscillator (gyro-BWO) experiment based on the same setups of electron gun and magnet system has achieved a frequency tuning band of 88 - 102.5 GHz by adjusting the cavity magnetic field. A maximum output power of 12 kW has been demonstrated in the measurement [1].

The whole gyro-TWA setup as shown in Fig. 1 includes a few key components, such as the cusp electron gun [2] to generate axial encircling electron beam, the input coupler [3, 4] to feed in the seed microwave signal, the helical corrugated interaction waveguide [5, 6], and the input and output microwave windows [7, 8]. The output radiation from the helically corrugated interaction wavegidie is in TE_{11} mode. However, the cloud profiling radar experiment requires a high-purity Gaussian beam. A mode convertor that is able to convert the TE_{11} mode into a Gaussian wave is required. Besides the requirement of high Gaussian content, the mode convertor needs to have low reflection and wide bandwidth to ensure stable operation of the gyro-TWA.

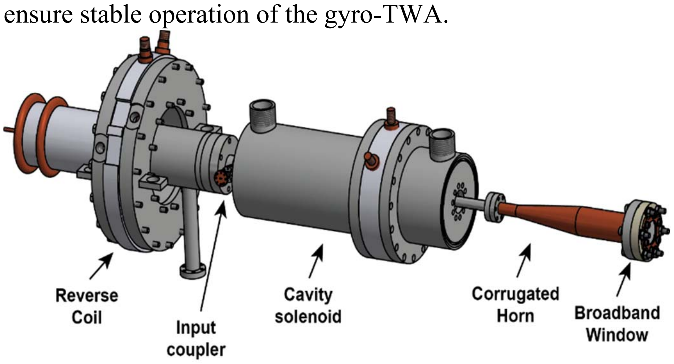

Fig. 1 The setup of the W-band TWA.

The mode convertor can be achieved by a Vlasov type launcher [9], a Potter horn, a dielectric loaded horn or a corrugated horn. The corrugated horn is a better solution as the others are either relatively narrow bandwidth or too lossy in high power application. In this paper, a corrugated horn [10] with $\sin^2$ profile was designed and the results are verified by measurement with a vector network analyzer (VNA).

II. DESIGN AND CONSTRUCTION

A prototype corrugated horn has been designed to verify the principle, as shown in Fig. 2. It is able to achieve a Gaussian coupling of 98% over the operating frequency range of 90 - 100 GHz and a reflection of -30 dB [11]. However to employ the corrugated horn in the gyro-TWA used for the cloud profiling radar application, an upgraded version is required to achieve an even higher Gaussian percentage as well as to seal the ultra-high vacuum.

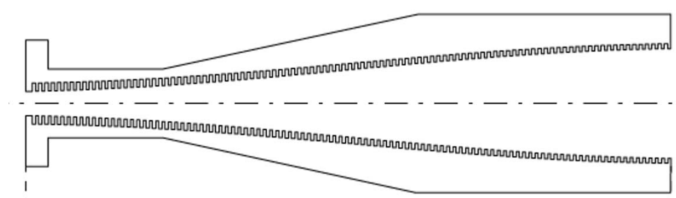

Fig.2. the previous designed corrugated horn.

When designing the corrugated horn in order to achieve a high Gaussian percentage, up to 99.5%, it is necessary to take the higher order modes into account. A small amount of TE_{12} and TM_{12} modes with correct phases is also required. The performance of the corrugated horn was simulated and optimized by using the mode-matching software, Mician uWave Wizard [12]. The corrugations was chosen to be linearly tapered in depth from $\lambda/2$ at the throat of the horn to $\lambda/4$ at the output aperture, in order to mainly an optimum impedance match between the horn and the output window to reduce the reflection. The simulation results show the horn is able to achieve a Gaussian percentage of 99.5% at the operation frequency range and TE_{11} mode reflection lower than -30 dB, which satisfies the design requirements.

The corrugated horn was then manufactured by electroforming method. An aluminum mandrel with the inner corrugated profile was firstly machined by a CNC machine. Then copper was grown on it to join the vacuum sealing flanges. The aluminum material was dissolved to leave the copper corrugated horn and the flanges, as shown in Fig. 3.

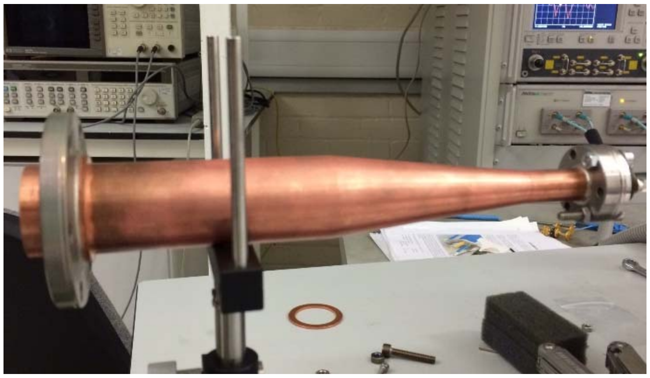

Fig. 3 The corrugation horn with vacuum sealing flanges.

III. Measurement Results

The reflection and far field mode pattern of the corrugated horn were measured by using a W-band VNA (model type Anritsu ME7808B). A -30 dB reflection was achieved over the frequency band of 90 - 100 GHz, as shown in Fig. 4.

The far field measurement shows about 99% of the transmitted power is within 29 degrees. The measured results were in excellent agreements with the simulated ones. To measure the Gaussian percentage of the field at the aperture, a near field scan using a WR10 waveguide was carried out and the field strength data was processed to get coupling coefficient with the fundamental Gaussian mode. From the measured contour plot it was calculated that the coupling coefficient was about 99.4%.

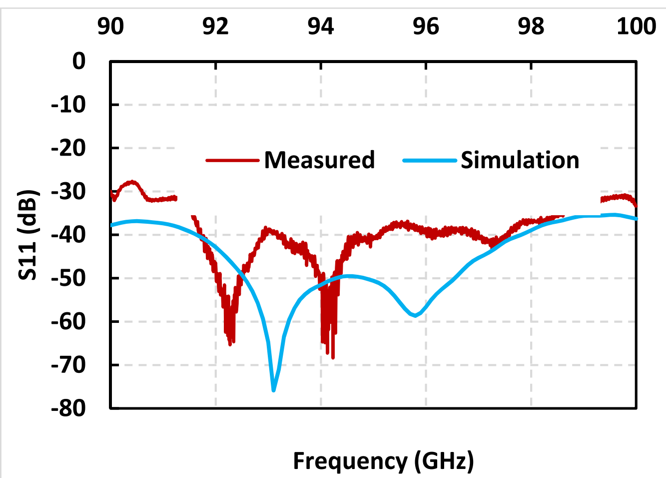

Fig. 4. Simulated and measurement results of the corrugated horn.

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